XXI.—*On the Mating Instinct in Moths* *.

By Alfred Goldsborough Mayer.

During the past summer the author carried out a series of experiments to determine the nature of the mating instincts of *Collosamia promethia*.

A large number of cocoons of this moth were kindly collected for the author by W. L. Tower, Esq , in the neighbourhood of Cambridge, Massachusetts, and others were found by the writer at Maplewood, New Jersey. Altogether 449 cocoons were obtained during the winter of 1898–99. These were allowed to remain out of doors in Cambridge (Mass.), where they were exposed to the winter's cold, and then on May 5 they were taken to Loggerhead Key, one of the Dry Tortugas Islands, Florida.

This situation was most favourable for the prosecution of the experiments, for this insect does not extend south of the Carolinas, and thus the moths were separated many hundreds of miles from others of their species. Moreover, Loggerhead Key is a small sandy island surrounded by many miles of ocean, and thus no interference with the experiments could come from the outside.

The cocoons were hung under the shade of some trees, where they were protected from the direct rays of the sun. It was remarkable that all but five of the moths (three females and two males) issued from the cocoons during the early morning hours between sunrise and 11 o'clock.

The following table will show the rate at which the moths issued from their cocoons :—

Date.	Number of males.	Number of females.	Total.
May 18.....	1	2	3
19.....	1	2	3
20.....	1	2	3
21.....	1	0	1
22.....	1	0	1
23.....	0	0	0
24.....	1	0	1
25.....	1	1	2
26.....	0	0	0
27.....	1	1	2
28.....	0	0	0
Carried forward	8	8	16

* This paper was delivered as the Presidential Address before the Cambridge (Mass.) Entomological Society in January 1900, and published in 'Psyche,' the Journal of the Club, in February.

Date.	Number of males.	Number of females.	Total.
Brought forward....	8	8	16
May 29.....	2	1	3
30.....	0	1	1
31.....	0	0	0
June 1.....	5	2	7
2.....	6	2	8
3.....	3	3	6
4.....	2	3	5
5.....	4	1	5
6.....	3	2	5
7.....	3	3	6
8.....	1	1	2
9.....	6	1	7
10.....	13	3	16
11.....	10	1	11
12.....	7	3	10
13.....	5	3	8
14.....	10	2	12
15.....	8	5	13
16.....	2	9	11
17.....	3	3	6
18.....	4	1	5
19.....	2	1	3
20.....	2	1	3
21.....	1	1	2
22.....	1	2	3
23.....	0	0	0
24.....	0	1	1
25.....	0	0	0
26.....	0	0	0
27.....	0	1	1
Total.....	111	65	176

It will be seen that 63 per cent. of the moths were males and 37 per cent. were females.

As is well known, in this moth the wings of the female are reddish brown in colour, while in the male they are black; also the antennæ of the males are large and bushy and of the females small and slender.

The male possesses the ability to seek out the female even though she be at a considerable distance.

The males usually fly towards the females in the afternoon hours between 2 o'clock and sunset, and it is a common thing to observe several dozen males fluttering about the place where the female is resting.

In seeking the female the male flies up against the wind until he comes into her near presence; then he often flutters to and fro in a bungling manner that for want of better words we might designate as "stupid" and "aimless." Often he may fly into the immediate neighbourhood of the female, and

even then he will often flutter away without attempting to mate with her. At other times, however, he will fly at once to her and mate immediately.

After issuing from the cocoon the female generally remains quiescent for some hours, until she is fertilized, after which she flies actively about and deposits her eggs.

During her period of rest the female remains with wings closed over her back; but when a male moth, or indeed any large object, comes near her within range of her vision she slowly and majestically opens and closes her wings several times.

The males when resting act in a similar manner, but are by no means so sensitive as the females.

In captivity the moths lived from three to five days.

Observations and Experiments.

The first experiments were directed to determine whether the male was attracted by the sight of the female or whether he merely perceived an odour emanating from her.

Five females were placed in a clear glass battery-jar, having a wide open mouth; the mouth was covered with a coarse-meshed mosquito-netting, to allow a free circulation of air between the interior of the jar and the outside.

Five males were liberated about 100 feet away from the jar; they immediately flew to it and fluttered about the mouth.

The jar was then inverted (placed mouth downward) and sand packed around the open end, so as to prevent the air escaping from the interior.

Thus the females remained visible through the glass, but no scent could come from them. Under these circumstances all the males flew away at once and some disappeared from sight.

When, however, the jar was turned open end up again all the males reappeared, flying excitedly round the mouth.

This experiment was often repeated, and always with the same result. The males never pay the least attention to females which are enclosed in a hermetically sealed preserving-jar of clear glass.

Assuming that the males are able to see through glass which appears transparent to us, we may conclude that sight alone is not sufficient to attract the male toward the female, or even to retain him in her presence when he is within a few inches of her.

Another experiment, which seems to show that the male

depends solely upon scent in seeking the female, may be performed as follows:—A female is wrapped in loose raw cotton, so as to be invisible and yet allow a scent to emanate from her. The males then fly to the cotton and, crawling all over it, flutter their wings excitedly and grasp the cotton repeatedly with their abdominal claspers.

In another series of experiments, the females were enclosed in a wooden box having a paper chimney rising from one end, the other end being open and covered with mosquito-netting.

This box was so arranged that a current of air blew in through the open end and out of the chimney. The females were invisible from the outside, and yet any scent from them would be carried up the chimney into the outer air.

When the males were liberated they flew to the mouth of the chimney and fluttered about in its neighbourhood. None came to the large open end of the box, into which the air was blowing.

I then poured some CS_2 in a large, flat, evaporating-dish, and placed it near the open end of the box, in such a manner that the fumes passed up the chimney and mingled with the scent from the female moths. The males, however, paid no attention to the new odour, and still fluttered around the chimney; nor did they seem to be disturbed by the fumes of ethyl mercaptan, which possesses a most nauseating and putrid odour. Evidently the scent arising from the females is sufficient to overpower the fumes of CS_2 or ethyl mercaptan, if, indeed, the males have any perception of the latter odours.

The entire abdomens of five females were cut off and placed upon a table, while the males were placed in a large mosquito-net cage about 5 feet away. Two males were liberated within five minutes of the time when the abdomens were cut off. They both flew to the recently severed abdomens and paid no attention to the abdomenless females in an adjacent cage.

I repeated this experiment many times, but in all subsequent trials the males paid no attention either to the severed abdomens or to the mutilated females. So far as positive results go, however, it appears that the scent which attracts the males emanates from the abdomen of the females.

When the eggs are cut out of the female she no longer attracts the males, nor do the detached eggs attract them.

Dead or dying females have no attraction, nor do the males come to the empty cocoon from which a female has issued.

When a female remains for some time in any place she seems to impart an odour to the locality, for males will continue to come to it for about two hours after she has left.

It is interesting to notice that the females increase in attractiveness as they grow older. This was repeatedly demonstrated as follows:—

Several females, all of which were about six hours old, were confined in a large cage made of mosquito-netting, thus allowing a free circulation of air. The same number of females about thirty hours old were placed in another similar cage about six feet away from the younger females. Out of thirty-seven males thirty-five came exclusively to the cage containing the older females. Of the two remaining males one came to the younger females and one divided his attention between both cages. When the females are made to exchange cages the males will still go to the cage containing the older females.

Upon testing females thirty hours old against females fifty-five hours old, it appeared that they were equally attractive. Of seven males three came to the females thirty hours old, one divided his attention between both cages, and three came to the fifty-five hour females. It thus appears that females about six hours old are not so attractive as are females one or two days old.

Virgin females are somewhat more attractive than fertilized ones of the same age. When the virgins are placed in a cage five feet away from a cage containing an equal number of fertilized females the majority of the males fly to the virgins. Thus out of eleven males eight came to the virgin females, two to the fertilized ones, and one to both cages.

Fertilized females are still quite attractive to males, however, and the males will readily mate with them. This last was first observed by Miss Caroline G. Soule in 1894. She had two female *promethia* moths, each one of which was mated with four males and still remained attractive to other males. In fact, as long as the female remained alive and in good health she held attractions for the male.

One of my males mated four times with three females, and three others mated three times each. The males will make frantic efforts to mate with a female which is at the time coupling with another male.

The male will fly toward the female with normal eagerness even though his entire abdomen be cut off, and he will still seek the female when, in addition to this, the sides of his thorax are covered with impervious glue. It is therefore evident that the spiracles are not the seat of the organs by which the male perceives the female scent.

If, on the other hand, the antennæ of the male be covered with shellac, glue, paraffin, Canada balsam, celloidin, or

photographic paste *, he no longer seeks the female, and displays no excitement even though within an inch of her. In five instances I removed the paste by dissolving it in water, and in four of these cases the males readily mated with the females. Upon again covering the antennæ with the paste the males again failed to notice the females when in close proximity to them.

There can be but little doubt that the organs by which the male perceives the female are situated in the antennæ; indeed it has long been recognized that the olfactory organs of insects are found chiefly upon the antennæ. Hauser (1880) and Kraepelin (1883) have given excellent descriptions of the minute anatomy of these organs, Hauser having carried out an elaborate series of physiological experiments to determine their functions. He cut off the antennæ of several species of insects and found that their sense of smell was then either greatly impaired or totally lost; covering their antennæ with melted paraffin gave the same results.

Hauser also found that when the antennæ of the male (*Saturnia pavonia*) were removed the moth never makes any attempt to mate.

Packard (1898) gives an excellent review of all researches relating to the anatomy and physiology of the olfactory organs in insects.

If the eye of a male (*Callosamia promethia*) be covered thickly with pitch or Brunswick black †, so as to preclude the possibility of sight remaining, the male will still mate in a normal manner when placed near the female.

It will be remembered that in this moth the male is black while the female is reddish brown; in accordance with the well-known theory of Darwin, the peculiar coloration of the male might be due to sexual selection on the part of the female. We might suppose, indeed, that the female preferred dark-coloured males, and thus under the influence of sexual selection the males became darker and darker, until the present melanic colour has been attained.

In 1897 the author showed that the melanic colour of the male of this moth is phylogenetically newer than the colour-pattern of the female, and this fact, so far as it goes, lends support to this theory of Darwin's.

In order to test this hypothesis I cut off the wings of a number of females, leaving only short stumps, from which all

* The photographic paste mentioned was "Stafford's white paste"; probably any impervious paste would serve as well.

† This substance is commonly used as microscopic cement, and is of a pitchy consistency and a dense brown-black colour.

the scales were carefully brushed. Male wings were then neatly glued to the stumps, and thus the female presented the appearance of a male. Under these circumstances the males mated with the female quite as readily as they would have done under normal conditions.

I then tried the experiment of gluing female wings upon the male. Here again the mating seemed to occur with normal frequency, and I was unable to detect that the females displayed any unusual aversion toward their effeminate-looking consorts.

It is also interesting to note that normal males pay no attention to males with female wings.

In another series of experiments the wings were cut entirely off of males and females and the scales brushed off of their bodies; and yet these shabby males were readily accepted by normal females, nor could I see that normal males displayed any aversion to mating with wingless females.

We are therefore forced to conclude that the melanic coloration of the male has not been brought about through the agency of sexual selection on the part of the female. In this connexion it is interesting to notice that Plateau (1897) concludes that insects are attracted only by the odours of flowers, and not at all by their colour.

In conclusion, it gives me great pleasure to express my gratitude to Miss Caroline G. Soule for advice and aid; to W. L. Tower, Esq., for his kindness in collecting many cocoons of the moth; and to Dr. Robert W. Fuller, who provided me with the reagents used in the manufacture of ethyl mercaptan.

Summary of Conclusions.

The male is positively chemotactic toward some substance which emanates from the abdomen of the female, and which he perceives through olfactory organs situated upon his antennæ.

Females thirty to sixty hours old are much more attractive to males than are young females five to ten hours old.

Virgin females are somewhat more attractive than are fertilized ones of the same age.

The male will mate at least four times either with the same or with different females.

Neither males nor females pay any attention to the appearance of their partners.

The melanic colour of the male has not been brought about by sexual selection on the part of the female.

Literature quoted.

Hauser, G. (1880).—Zeitschrift für wissen. Zool. Bd. xxxiv. pp. 367–403, Taf. iii.
Kraepelin, K. (1883).—Ueber des Geruchsorgane der Gliedertiere. 48 pp., 3 Taf. Hamburg.
Mayer, A. G. (1897).—Bulletin Museum Comp. Zool. at Harvard College, vol. xxx. pp. 178–180, pl. iii. figs. 24–41.
Packard, A. S. (1898).—A Text-book of Entomology. Pp. vi, 729; 654 figs. Macmillan & Co.
Plateau, F. (1897).—Bull. Acad. Roy. Sci. Belgique, tom. xxxiv. pp. 601–644, 847–880.
Soule, Caroline G. (1894).—'Psyche': the Journal of the Cambridge Entomological Club, vol. vii. p. 155.

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XXII.—*On British Species of* Siphonostoma.

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[Plate IV.]

The two most familiar species of *Siphonostoma* (*Flabellifera*) are *S. affinis*, the typical northern form, and *S. diplochaïtos*, the typical Mediterranean form. It is, however, worthy of notice that while Cunningham and Ramage * suggest that the two are identical, St. Joseph † says there can be no possibility of confusion between the two. In the vicinity of Millport Marine Station a species of *Siphonostoma* occurs in great abundance in the nests of *Lima hians*, and a collection made there during this summer has enabled me to make some observations on the specific characters. For purposes of comparison, Mr. E. J. Allen, of the Plymouth Marine Station, kindly furnished me with twenty-one specimens of the species found in the neighbourhood of Plymouth. The two forms are distinct, the Millport specimens agreeing most closely with *S. diplochaïtos*, Otto, the Plymouth specimens with *S. affinis*, Sars, as defined by St. Joseph. Before proceeding to describe the specimens, it may be well to give in tabular form St. Joseph's list of the specific differences between the two:—

* "Polychæta Sedentaria of the Firth of Forth," Trans. Roy. Soc. Edin. xxxiii. (1888), p. 677.

† "Annélides Polychètes des Côtes de Dinard," Ann. Sci. Nat. (Zool.) xvii. (1894) p. 96.